(19) Europäisches Patentamt
European Patent Office
Office européen des brevets

(11) EP 1 111 343 A1

(12) EUROPEAN PATENT APPLICATION

(43) Date of publication:
27.06.2001 Bulletin 2001/26

(51) Int Cl.7: G01D 3/08, F02D 9/00,
G01B 7/30

(21) Application number: 00127702.9

(22) Date of filing: 18.12.2000

(84) Designated Contracting States:
AT BE CH CY DE DK ES FI FR GB GR IE IT LI LU MC NL PT SE TR
Designated Extension States:
AL LT LV MK RO SI

(30) Priority: 21.12.1999 JP 36218099

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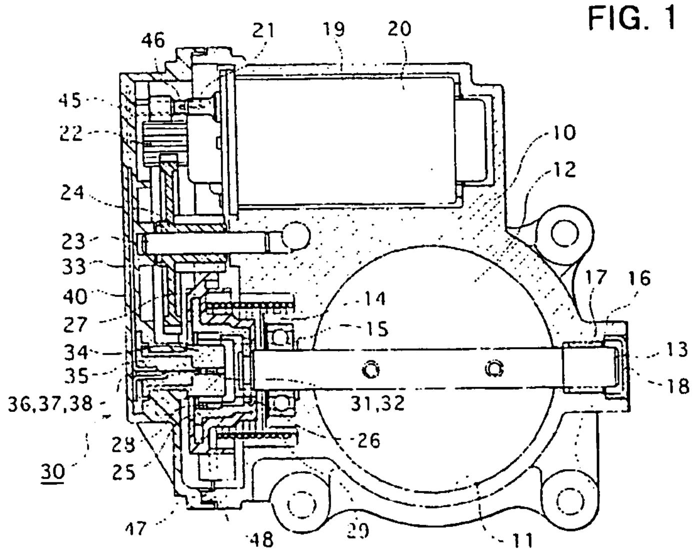
(54) **Method and device for contactless position measurement**

(57) If outputs of a couple of Hall ICs (31, 32) constituting a throttle valve position sensor (30) are within an operating range of throttle valve position, and if a relationship between the outputs are within a predetermined error range, both the Hall ICs (31, 32) are determined to be normal. In contrast, if the outputs are equal to an upper clamp voltage or a lower clamp voltage, and if a relationship between the outputs is out of the predetermined error range, at least one of the Hall ICs is determined to be abnormal. Furthermore, if the outputs are within a failure reference voltage range, it is determined that there is an abnormality between the throttle valve position sensor and an ECU. In this way, abnormalities in the sensor (30) and abnormalities between the sensor (30) and the ECU can also be detected.

FIG. 1



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supported by a bearing holder 16 of the throttle body 10. A cap 18 is fitted into the bearing holder 16 of the throttle body 10. The amount of the intake air supplied to the internal combustion engine is adjusted by a size of an opening that is formed as the throttle valve 12 is rotated relative to the intake air passage 11 of the throttle body 10.

[0010] The electric motor 20 is housed in a motor housing 19 defined in the throttle body 10. The motor 20 has a motor power supply terminal 21, which protrudes from the motor 20, and a pinion gear 22, which is fitted around a distal end of an output shaft of the motor 20. Around a rotor 25 that is secured to the one end of the rotatable shaft 13, a resin gear 27 is coupled by insert molding. On an inner peripheral surface of the rotor 25, there is fixedly secured a cylindrical permanent magnet 28. The pinion gear 22 is in gear engagement with the resin gear 27 via an intermediate reduction gear 24 that rotates about a fixed shaft 23 secured to the throttle body 10. Around the outer peripheral of the resin gear 27 that is integral with the rotor 25, there is provided a return coil spring 29 for urging the throttle valve 12 to the initial throttle valve position via the rotatable shaft 13 when the motor 20 is turned off by, for example, turning off an ignition switch (not shown). Positioning holes 26 extend through the rotor 25 for securing the rotor 25 at a position that coincides with an idle position of the rotatable shaft 13.

[0011] In the present embodiment, the throttle valve 12 can be rotated from a full throttle valve position (90 degrees) through a closed throttle valve position (0 degree) to an initial throttle valve position (- 10 degrees), which is a mechanical stop position of the throttle valve 12.

[0012] The throttle valve position sensor 30 includes the cylindrical permanent magnet 28, a couple of Hall ICs 31, 32, a lead frame 33 and a split stator 34. The cylindrical permanent magnet 28 acts as a magnetic field generating source. The Hall ICs 31, 32 act as redundant non-contact type measurement elements and are integrally formed with a resin sensor cover 40. The lead frame 33 is made of a conductive thin metal plate for electrically connecting the Hall ICs 31, 32 with the external ECU. The split stator 34 is made of magnetic material for concentrating the magnetic flux on the Hall ICs 31, 32.

[0013] The Hall ICs 31, 32 are opposed to the inner peripheral surface of the permanent magnet 28 to cause generation of electromotive force in response to generation of an N pole magnetic filed or a S pole magnetic field on their magneto-sensitive surfaces (generating a positive (+) electric potential and a negative (-) electric potential by the N pole magnetic field and the S pole magnetic field, respectively). The Hall ICs 31, 32 of the present embodiment are arranged in parallel and are arranged to face in opposite directions (rotated 180 degrees).

[0014] With reference to FIG. 2, the lead frame 33 is made, for example, of a copper plate (conductive thin metal plate). The lead frame 33 includes a signal input terminal (VDD) 41, output terminals (OUT 1, OUT 2) 42, 43 and a ground terminal (GND) 44. The signal input terminal (VDD) 41 is fed, for example, with a 5 (V) power supply voltage. The output terminals (OUT 1, OUT 2) 42, 43 output a signal indicative of a position of the throttle valve 12. Each of a signal input lead (VDD) 36, a ground lead (GND) 37 and an output lead (OUT 1, OUT 2) 38 of the Hall ICs 31, 32 is connected with the lead frame 33. A connection between each described lead and the lead frame 33 is covered with a connection holder 35 made of a thermoplastic resin, such as PBT. Two stator halves constituting the split stator 34 are secured around the outer peripheral of the connection holder 35 in a manner that provides a predetermined gap between the stator 34 and the Hall ICs 31, 32.

[0015] The sensor cover 40 closes an opening of the throttle body 10. The sensor cover 40 is a thermoplastic resin molded product (such as, one made of PBT), which is lightweight, easy to manufacture and inexpensive and electrically insulates each terminal of the throttle valve position sensor 30 from other terminals. A recess 48 is formed on the sensor cover 40 to engage with a protrusion 47 formed at the opening side of the throttle body 10. Upon engagement of the recess 48 and the protrusion 47, the sensor cover 40 is secured to the throttle body 10 by a clip (not shown), completing the assembling of the sensor cover 40 and the throttle body 10. When the protrusion 47 of the throttle body 10 is engaged with the recess 48 of the sensor cover 40, the Hall ICs 31, 32, which are secured on the sensor cover 40, are correctly aligned with the permanent magnet 28, which is secured to the inner peripheral side of the rotor 25 that integrally rotates with the rotatable shaft 13 of the throttle valve 12.

[0016] Furthermore, as shown in FIG. 2, the connector 50 that is integrally formed on a lateral side surface of the sensor cover 40 has a distal end 51 of the signal input terminal 41, distal ends 52, 53 of the output terminals 42, 43, a distal end 54 of the ground terminal 44 and distal ends 55, 56 of a motor power feed terminal 45 of the motor 20. Other ends of the motor power feed terminal 45 are integrally connected with a motor connection terminal 46. Once the throttle body 10 is assembled with the sensor cover 40, the motor power supply terminal 21 of the motor 20 is connected to the motor power feed terminal 45 via the motor connection terminal 46.

[0017] A flow of throttle valve position information provided through an internal computation in the Hall ICs 31, 32 will now be described with reference to FIG 3.

[0018] With reference to FIG. 3, a rotational angle value indicative of a position of the throttle valve 12 is measured with a rotational angle measurement unit 311, 321 via a Hall element in each Hall IC 31, 32. The measured rotational angle value is then inputted to an A/D converter 312, 322. Furthermore, a temperature value

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normal, so that control skips step S106.

[0027] Then, control moves to step S107 where it is determined whether the output 2 of the other Hall IC 32 read at step S104 is within a predetermined tolerance range, for example, within a range of 0.9 to 1.1 (V). If the answer at step S107 is NO, control passes to step S108 where it is determined that the Hall IC 32 is abnormal. On the other hand, if the answer at step S107 is YES, it is determined that the Hall IC 32 is normal, so that control skips step S108.

[0028] Then, control passes to step S109 where it is determined whether both the Hall ICs 31, 32 are abnormal. If the answer at step S109 is YES, control passes to step S110 where the flag FDFAIL, which indicates that both the Hall ICs 31, 32 are abnormal, is set to "1". Then, control passes to step S111 where the power supply to the motor 20 is turned off, so that the drive control of the throttle valve 12 via the motor 20 is prohibited (or stopped), and the throttle valve 12 is fixed to the initial throttle valve position. Then, the routine is terminated.

[0029] On the other hand, if the answer at step S109 is NO, that is, one of the Hall ICs 31, 32 is abnormal, control passes to step S112 where the flag FSFAIL, which indicates that one of the Hall ICs 31, 32 is abnormal, is set to "1". Then, the routine is terminated.

[0030] Once the flag FSFAIL is set to "1", the drive control of the throttle valve 12 via the motor 20 is resumed and is conducted based on the output of the remaining normal Hall IC 31, 32 via a control routine (not shown), and an operation mode of the vehicle is changed to a limp-home mode. A time point of resuming the drive control of the throttle valve 12 via the motor 20 is when a demand for a change in an operating condition of the vehicle (such as a demand for acceleration or deceleration) is received from a vehicle driver. This is determined based on a change in output of an accelerator pedal position sensor, a brake switch or the like.

[0031] During the limp-home mode of the vehicle operation, an upper protective limit is imposed on the position of the throttle valve 12 for safety reasons. Furthermore, upper protective limits are also respectively imposed on parameters provided for controlling the operating condition of the internal combustion engine, such as the amount of intake air, the engine speed and the like. If any of these parameters reaches its upper protective limit, the drive control of the throttle valve 12 via the motor prohibits further incrementation of the position of the throttle valve 12. Furthermore, after resuming the drive control of the throttle valve 12 via the motor 20, if a relationship between the described parameter and the one of the Hall ICs 31, 32, which has been determined to be normal, is out of a predetermined range, this Hall IC is also determined to be abnormal. Thus, the power supply to the motor 20 is turned off to prohibit (or stop) the drive control of the throttle valve 12 via the motor 20.

[0032] The failure determination according to the present invention will be further described with reference to FIG. 4A. The upper clamp voltage (or the maximum output voltage) of 4.7 (V) of the Hall ICs 31, 32 is set to exceed an upper tolerance limit of 4.6 (V) provided for the output voltage of 4.5 (V) at the upper border of the operating range of Hall ICs 31, 32. Furthermore, the lower clamp voltage (or the minimum output voltage) of 0.3 (V) of the Hall ICs 31, 32 is set to exceed a lower tolerance limit of 0.4 (V) provided for the output voltage of 0.5 (V) at the lower border of the operating range of the Hall ICs 31, 32. The upper clamp voltage of 4.7 (V) and the lower clamp voltage of 0.3 (V) are also set to fall between an upper failure reference voltage range that is higher than 4.7 (v) and a lower failure reference voltage range that is lower than 0.3 (V). The upper failure reference voltage and the lower failure reference voltage are set by the ECU and are provided at upper and lower borders of a power supply voltage of 5 (V) applied to the Hall ICs 31, 32, respectively.

[0033] That is, if the sensor output voltage of each of the Hall ICs 31, 32 is between the upper tolerance limit of 4.6 (V) and the lower tolerance limit of 0.4 (V), and if a relationship between the sensor output voltage of the Hall IC 31 and the sensor output voltage of the Hall IC 32 is within the predetermined error range, both the Hall ICs 31, 32 are determined to be normal. Also, if the sensor output voltage of the Hall IC 32 is in a range of 4.6 (V) to 4.7 (V), and if the relationship between the sensor output voltage of the Hall IC 31 and the sensor output voltage of the Hall IC 32 is within the predetermined error range, both the Hall ICs 31, 32 are also determined to be normal. In contrast, if the sensor output voltage of the throttle valve position sensor 30 is equal to the upper clamp voltage of 4.7 (V) or the lower clamp voltage of 0.3 (V), and if the relationship between the sensor output voltage of the Hall IC 31 and the sensor output voltage of the Hall IC 32 is out of the predetermined error range, at least one of the Hall ICs 31, 32 is determined to be abnormal due to, for example, disconnection or short circuit. Furthermore, if the sensor output voltage of the throttle valve position sensor 30 is within the upper failure reference voltage range that is above the voltage of 4.7 (V) or within the lower failure reference voltage range that is lower than the voltage of 0.3 (V), it is determined that a connection (such as a wire harness or the like) between the throttle valve position sensor 30 and the ECU is abnormal due to, for example, disconnection or short circuit.

[0034] In this way, in the throttle valve position sensor 30, an abnormality of the Hall ICs 31, 32 can be detected throughout the entire operating range of the throttle valve position including the high throttle valve position zone, and also an abnormality of the connection between the throttle valve position sensor 30 and the ECU can be detected. Thus, an appropriate adjustment can be made to detect all failure modes.

[0035] Additional advantages and modifications will readily occur to those skilled in the art. The invention in its broader terms is therefore, not limited to the specific details, representative apparatus, and illustrative exam-

ment elements (31, 32), respectively.

8. An apparatus for processing an output of a position measurement sensor according to claim 7, characterized in that said movable body (12) is a throttle valve that adjusts an amount of intake air supplied to an internal combustion engine, and further characterized by control means (S101-S112) for detecting an abnormality of each said measurement element (31, 32) based on an output voltage of each said measurement element (31, 32) that is outputted while said throttle valve (12) is being returned to an initial throttle valve position within an operating range of said throttle valve (12).

9. An apparatus for processing an output of a position measurement sensor according to claim 8, characterized in that if one of said measurement elements (31, 32) is determined to be abnormal by said control means (S101-S112), said control means (S101-S112) uses other of said measurement elements (31, 32), which is determined to be normal by said control means, to resume a drive control operation of said throttle valve (12).

10. An apparatus for processing an output of a position measurement sensor according to claim 9, characterized in that a time point of resuming said drive control operation of said throttle valve (12) by said control means (S101-S112) is when a demand for a change in an operating condition of a vehicle is made.

11. An apparatus for processing an output of a position measurement sensor according to any one of claims 8 to 10, characterized in that in said drive control operation of said throttle valve (12) that is carried out when said one of said measurement elements (31, 32) is determined to be abnormal by said control means (S101-S112), said control means (S101-S112) imposes upper protective limits on a position of said throttle valve and also on a parameter provided for controlling an operating condition of said internal combustion engine, respectively.

12. An apparatus for processing an output of a position measurement sensor according to claim 11, characterized in that in said drive control operation of said throttle valve (12) that is carried out when said one of said measurement elements (31, 32) is determined to be abnormal by said control means (S101-S112), if a relationship between said position of said throttle valve (12) and said parameter provided for controlling said operating condition of said internal combustion engine is out of a predetermined range, said control means (S101-S112) turns off a power supply to an electric motor (20) that drives said throttle valve (12) to open or close said throttle valve (12).

FIG. 2

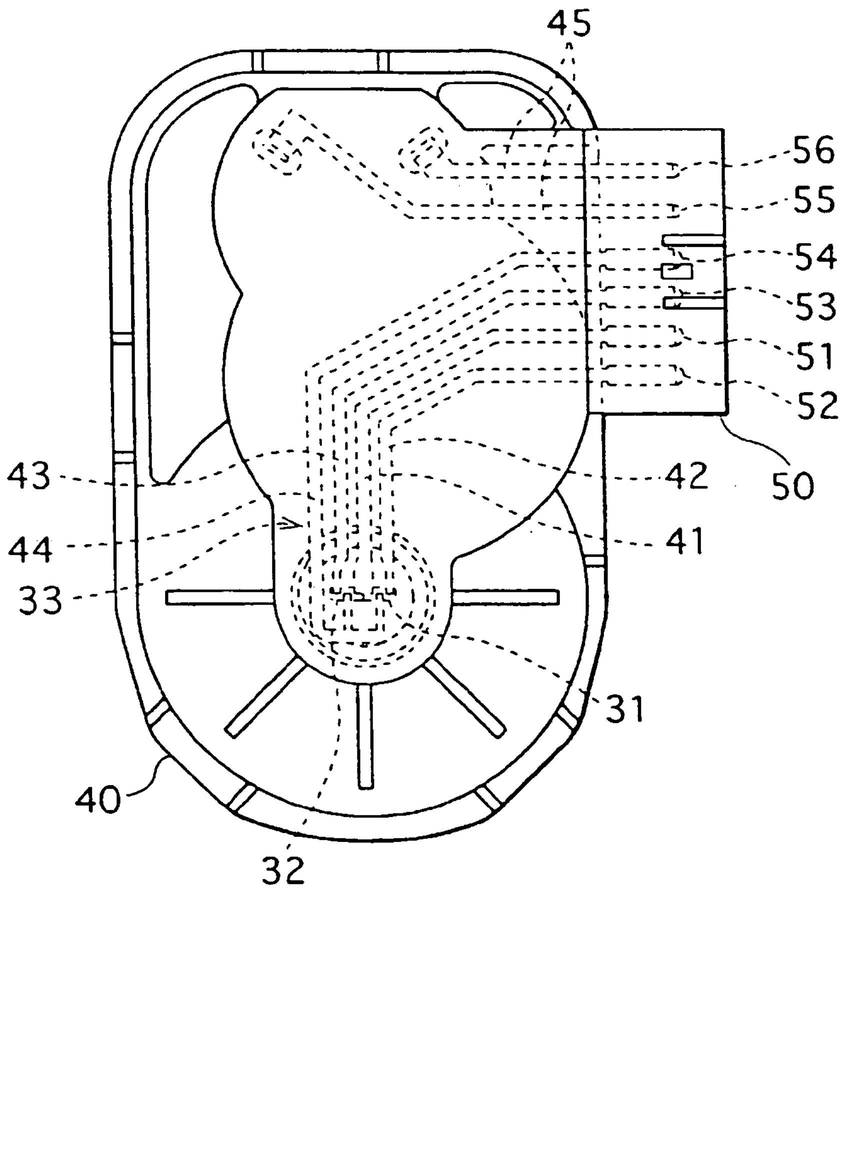
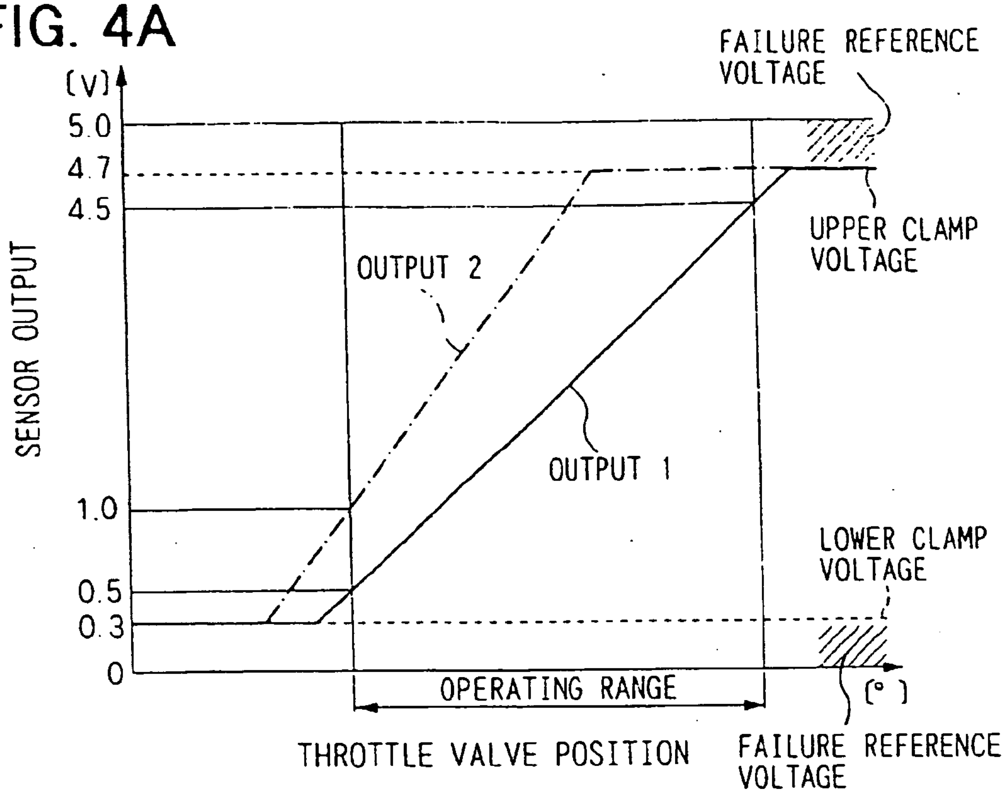


FIG. 4A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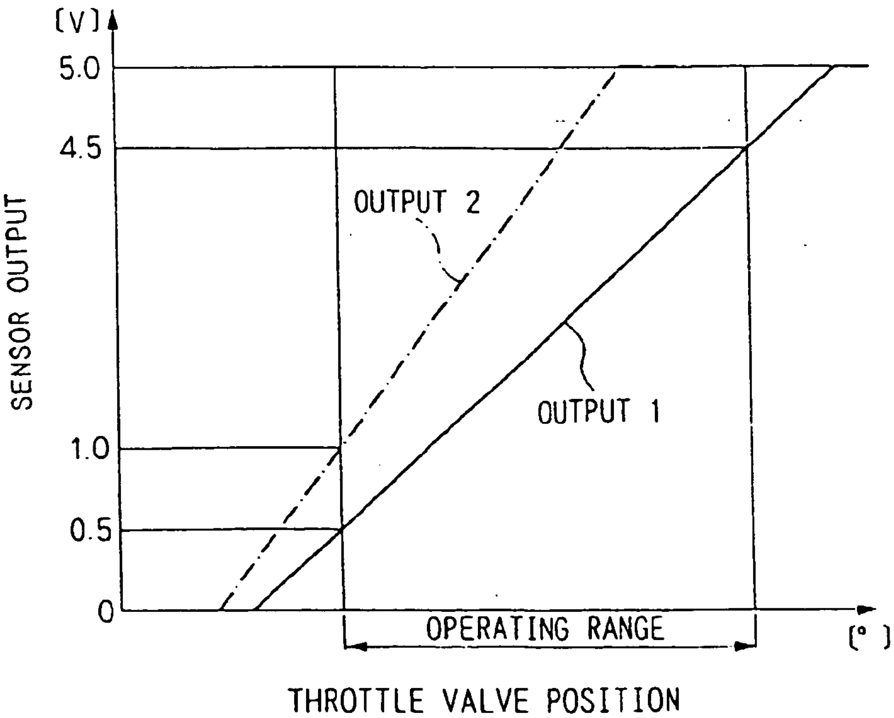
SENSOR OUTPUT
FAILURE REFERENCE VOLTAGE
UPPER CLAMP VOLTAGE
OUTPUT 2
OUTPUT 1
LOWER CLAMP VOLTAGE
OPERATING RANGE
[°]
THROTTLE VALVE POSITION
FAILURE REFERENCE VOLTAGE

FIG. 4B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SENSOR OUTPUT
OUTPUT 2
OUTPUT 1
OPERATING RANGE
[°]
THROTTLE VALVE POSITION

European Patent Office

EUROPEAN SEARCH REPORT

Application Number
EP 00 12 7702

DOCUMENTS CONSIDERED TO BE RELEVANT

Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	CLASSIFICATION OF THE APPLICATION (Int.Cl.7)
A	US 5 544 000 A (SUZUKI HARUHIKO ET AL) 6 August 1996 (1996-08-06) * column 10, line 6 - line 40; figures 10-12,21-23 * -----	1-12	G01D3/08 F02D9/00 G01B7/30

TECHNICAL FIELDS SEARCHED (Int.Cl.7)
G01D
F02D
G01B

The present search report has been drawn up for all claims

Place of search	Date of completion of the search	Examiner
THE HAGUE	2 April 2001	Lut, K

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